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(71)Applicant : NISSHIN STEEL CO LTD
(72)Inventor : TAGASHIRA SATOSHI
YAMADA TOSHIRO

(54) PRODUCTION OF ULTRAHIGH STRENGTH STEEL

(57)Abstract:
PURPOSE: To obtain an ultrahigh strength steel having 1600 to 2300N/mm2 class tensile strength and excellent in ductility.
CONSTITUTION: A steel having a composition consisting of, by weight, 0.4-1.0% C, 1.2-3.0% Si, 0.3-2.0% Mn, 0.2-1.5% Cr, and the balance Fe with inevitable impurity elements or a steel where, as necessary, one or ≥2 kinds among 0.05-0.5% Mo, 0.05-0.5% V, and 0.01-0.5% Nb are further incorporated into the composition is heated up to a temp. not lower than the AC3 transformation point to undergo complete austenitization. The steel is cooled from the above- mentioned temp. to a temp. between the Ms point and <350°C at a cooling velocity higher than the velocity at which the nose in the TTT diagram passes. The steel is isothermally held in the above-mentioned temp. region for 10-60min and then air-cooled down to room temp. or cooled at the cooling velocity not lower than air cooling velocity. By this method, the ultrahigh strength steel having a composite structure containing bainite and residual austenite as main phases and also having 1600 to 2300N/mm2 tensile strength can be produced.

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* NOTICES *

CLAIMS

[Claim(s)]
[Claim 1] C: 0.4-1.0 Weight % and Si:1.2-3.0 Weight % and Mn:0.3-2.0 Weight % and Cr:0.2-1.5 Weight %, the steel which consists of the remainder Fe and an unescapable impurity element is heated to the temperature beyond an Ac3 transformation point. With a bigger cooling rate than the rate which passes the nose of a TTT diagram from this temperature after austenitizing completely, above an Ms point to the temperature of less than 350 degrees C cooling -- this temperature region -- for 10 - 60 minutes -- constant temperature -- the complex tissue which consists of cooling with the cooling rate more than air cooling or air cooling to a room temperature after holding and which made bainite and retained austenite the main phase -- having -- and tensile strength -- the manufacture approach of the ultrahigh strength steel of 1600-2300N/mm2.
[Claim 2] C: 0.4-1.0 Weight % and Si:1.2-3.0 weight % and Mn:0.3-2.0 Weight % and Cr:0.2-1.5 Weight %, further -- 0.05-0.5 Mo of weight %, and 0.05-0.5 V of weight % -- or -- 0.01-0.5 Any one sort of the weight %Nb, or two sorts or more It contains, Steel with which the remainder consists of Fe and an unescapable impurity element, it heats to the temperature beyond an Ac3 transformation point. After austenitizing completely With a bigger cooling rate than the rate which passes the nose of a TTT diagram from this temperature, above an Ms point to the temperature of less than 350 degrees C, cooling -- this temperature region -- for 10 - 60 minutes -- constant temperature -- the complex tissue which consists of cooling with the cooling rate more than air cooling or air cooling to a room temperature after holding and which made bainite and retained austenite the main phase -- having -- and tensile strength -- the manufacture approach of the ultrahigh strength steel of 1600-2300N/mm2.
[Claim 3] For retained austenite, carbon concentration is 1.5. The manufacture approach of the ultrahigh strength steel according to claim 1 or 2 which is more than weight %.
[Claim 4] Retained austenite is the manufacture approach of ultrahigh strength steel according to claim 1, 2, or 3 that the volume occupied to the whole is 15 to 30 volume %.
[Claim 5] The ultrahigh strength steel concerned is the manufacture approach of the ultrahigh strength steel according to claim 1, 2, 3, or 4 which is what has 10% or more of elongation.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Industrial Application] This invention is 2 (Newton / mm2) the tensile strength of 1600-2300Ns/mm which has the complex tissue which makes bainite and retained austenite the main phase. It is related with the manufacture approach of the ultrahigh strength steel of class.
[0002]
[Description of the Prior Art] It is using high carbon steel as steel materials for machine structural parts with which high reinforcement is demanded quenching-and-tempering [former] material, Many bainitic steel material has been used. However, these steel materials are lacking in toughness generally, That that service condition is remarkably restrained when using it to the member as which ductility and shock resistance are required ****, It was not rare it to have been obliged to compensate lack of toughness with the increment in the dimension of a member depending on the case, for this reason to have caused weight increase.
[0003] Conventionally, they are 1600 N/mm two or more tensile strength the case where high intensity material is manufactured using high-carbon steel. (it may be hereafter called TS for short) Although it is common to perform hardening-tempering processing if it is going to strengthen, high ductility-toughness cannot be acquired by this approach. A metal texture depends one with the usual hardening tempering material lacking in toughness on his being the hard organization which makes martensite and bainite a subject.
[0004] The method of improving ductility was proposed maintaining high intensity by considering as the mixed organization of bainite and retained austenite in JP,58-42246,B that this problem should be solved. In conventional bainitic steel, TS was that from which about 30% of all elongation is acquired to all elongation being about 10% at the 2nd 1200Ns [/mm] same class in the 2nd 1200Ns [/mm] class according to this approach.
[0005] Moreover, the approach TS acquired about 30% of elongation by the 2nd 1500Ns [/mm] class was shown to JP,3-215623,A by by similarly making a metal texture the mixed organization of bainite and retained austenite.
[0006]
[Problem(s) to be Solved by the Invention] By the approach proposed by said official report, even if it calls it high intensity, about 1600Ns /of TS are [mm] to 2 at the maximum. For example, in the example of the latter official report, the thing of 2 was max 164 kgf(s)/mm, and it was difficult to obtain TS beyond this.
[0007] This invention solves this trouble and it aims at TS obtaining ductile good ultrahigh strength steel by the 2nd 1600-2300Ns [/mm] class.
[0008]
[Means for Solving the Problem] According to this invention, it is C:0.4-1.0. Weight %, Si: 1.2-3.0 Weight % and Mn:0.3-2.0 Weight % and Cr:0.2-1.5 % of the weight, It is the steel which consists of the remainder Fe and an unescapable impurity element to this steel further Mo of weight %, and 0.05-0.5 V of weight %, or 0.01-0.5 Any one sort of the weight %Nb, or two sorts or more 0.05-0.5 With a bigger cooling rate than the rate which passes the nose of a TTT diagram from this temperature after heating the steel made to

contain to the temperature beyond an Ac3 transformation point and austenitizing it completely, above an Ms point to the temperature of less than 350 degrees C cooling -- this temperature region -- for 10 - 60 minutes -- constant temperature -- to a room temperature, after holding It has the complex tissue which consists of cooling with the cooling rate more than air cooling or air cooling and which made bainite and retained austenite the main phase, and tensile strength offers the 1600-2300Ns /of the manufacture approaches of the ultrahigh strength steel of 2 mm.

[0009]

[Function] the steel of the component presentation according to this invention -- a lower bainite field -- constant temperature -- if it holds -- the mixed organization of remarkable detailed lower bainite and retained austenite -- generating -- TRIP phenomenon of retained austenite (transformation induction plasticity: Transformation Induced-Plasticity) Though TS is the 2nd 1600-2300Ns [/mm] class, the ultrahigh strength steel in which elongation (El) has 10 - 20% of good on-the-strength-ductility balance is obtained. That is, the steel manufactured according to this invention method depends on the TRIP phenomenon [that the toughness which was very excellent is shown] of retained austenite.

[0010] In this invention, it has a large operation of Si that the complex tissue which consists of retained austenite and lower bainite is obtained. That is, since Si has the operation which controls generation of carbide when the transformation to bainite of the carbon steel which contains Si so much is carried out, the carbon atom in bainite is discharged in a non-metamorphosed austenite, for this reason the carbon concentration in a non-metamorphosed austenite rises, and it is a martensitic transformation point. (Ms point) It falls below to a room temperature. For this reason, even if it cools steel to a room temperature, martensite is not generated but the mixed organization of bainite and retained austenite is obtained.

[0011] In the steel which does not contain Si, since a deposit of carbide is followed on advance and coincidence of a transformation to bainite, concentration of the carbon atom to the inside of a non-metamorphosed austenite is inadequate, and the mixed organization of retained austenite and bainite cannot be obtained.

[0012] On the other hand, Si is an element which promotes graphitization, Since the danger of producing graphitization at the time of softening etc. in the case of the steel containing a lot of carbon is large, in order to control this, the large element of a graphitization deterrent must be added. It corrects, A graphitization suppression element must not check the toughness of a bainite texture.

[0013] Moreover, although the mixed organization of retained austenite and bainite can be obtained in the steel which consists of a chemical entity of only C-Si-Mn simply, since the rate of a transformation to bainite is quick, it is difficult [it] to control in the suitable amount of retained austenites. Therefore, the alloy element of suitable others which control a transformation to bainite in order to obtain the suitable amount of retained austenites, and generate effective retained austenite to ductility must be added.

[0014] moreover In order to coexist with lower bainite and for retained austenite to show the phenomenon of transformation induction plasticity Although the carbon concentration in retained austenite is required 1.5% or more, even if it holds the steel of a simple C-Si-Mn system to the isothermal transformation temperature field of the bainite concerned, carbon concentration high in this way cannot be obtained.

[0015] In order to attain the aforementioned purpose, ** with required taking such a thing into consideration synthetically and deciding the component presentation of steel This invention persons, if Cr and the steel which was further alike and carried out optimum dose addition of Mo, V, the Nb, etc. are used as a result of the fundamental research on these points in addition to C-Si and Mn Graphitization resistance It can be made to improve. And detailed lower bainite generated at the time of transformation-to-bainite processing, the complex tissue which consists of stable retained austenite and detailed lower bainite generated, and TS which was very excellent in on-the-strength-ductility balance found out that the ultrahigh strength steel of the 2nd 1600-2300Ns [/mm] class was obtained.

[0016] An operation of each component of the steel according to this invention and the reason for regulation of the content range are explained below.

[0017] C, It is an austenite stabilization element, It is an element indispensable to a transformation to bainite. The addition influences greatly the amount of retained austenites finally generated, and C addition

cannot obtain high intensity at less than 0.4%. Moreover, if the amount of C exceeds 1.0%, there will be too many amounts of retained austenites to generate, and reinforcement will fall on the contrary. It follows, In order to obtain the suitable amount of retained austenites, it is necessary to make the amount of C into 0.4 - 1.0% of range. In this invention steel, the desirable amount of retained austenites is 15 to 30 volume %.

[0018] Si is an element which controls generation of carbide, and in order to obtain stable retained austenite with high C concentration, it is an indispensable element. The above-mentioned effectiveness has the thin amount of Si at under 1.2 %, When the amount of Si exceeds 3.0 % on the contrary, a transformation to bainite not only being controlled remarkably but it is, It comes to be accompanied by remarkable difficulty by the production process of steel, such as hot rolling-cold rolling. Therefore, the amount of Si is limited to 1.2 - 3.0% of range.

[0019] Mn is an austenite stabilization element, The operation which inhibits generation of a pearlite etc. is offered by raising hardenability. However, since the amount of Mn has the insufficient hardenability of less than 0.3%, and the cooling rate of a core is slow when the board thickness of steel is thick, a pearlite etc. may be generated and retained austenite sufficient in this case is no longer obtained. When the amount of Mn exceeds 2.0%, the rate of a transformation to bainite becomes slow and it becomes impossible moreover, to obtain too sufficient retained austenite. For this reason, the amount of Mn is limited to 0.3 - 2.0%.

[0020] Cr is an element which acts effective in controlling the graphitization which takes place into softening of hot-rolling material, and is an element which has the operation which extends the field where a transformation to bainite is delayed and retained austenite is obtained. In order to prevent graphitization, the amount of Cr(s) is required for at least 0.2%, but even if it adds exceeding 1.5%, balling-up of the cementite at the time of about [that the effectiveness beyond it cannot be expected to suppression of graphitization] and softening is made difficult, and since there is an inclination to degrade the plasticity of the bainite itself, the amount of Cr(s) is limited to 0.2 - 1.5%.

[0021] Mo and V are elements into which the gestalt of a transformation of bainite is changed a lot, By carrying out optimum dose addition, the operation which makes a bainite texture make it detailed is offered, and the effectiveness which raises TS and toughness by this is done so. furthermore, V has the effectiveness which makes detailed austenite particle size at the time of heating steel in an austenite region -- if optimum dose addition of the V is carried out A transformation to bainite can also be promoted.

[0022] Mo has little detailed-ized effectiveness of bainite at less than 0.05% of addition, Even if it adds again exceeding 0.5%, detailed-ization beyond it cannot be desired, In order to bring a failure to generation of rather healthy bainite, it is necessary to limit to 0.05 - 0.5%. Moreover, V has little detailed-ized effectiveness of bainite at 0.05% or less of addition, Even if it adds again exceeding 0.50%, since it becomes generation of the rather healthy bainite same with the case of about [that it cannot wish] and Mo with a failure, it is necessary to limit the effectiveness beyond it to 0.05 - 0.5%.

[0023] A transformation to bainite is promoted according to the effectiveness which makes detailed austenite particle size at the time of heating in an austenite region, and Nb is detailed and is an element which has the operation which makes bainite with high toughness generate. However, there is little effectiveness that an addition makes austenite particle size detailed at less than 0.01%, Sufficient effectiveness for detailed-izing of bainite is not demonstrated, and even if it adds exceeding 0.5%, since effectiveness beyond it cannot be desired, it is limited to 0.01 - 0.5%.

[0024] To a degree The heat treatment conditions of this invention method are explained.

[0025] If in charge of manufacture of this invention steel, it is usually the usual hot rolling about the steel of the above-mentioned component presentation range, Softening, Cold rolling etc. is performed suitably, a steel strip or a steel plate is manufactured, and transformation-to-bainite processing is presented with this. as long as it manufactures at the usual process in this invention steel which controlled the graphitization inclination, there are few possibilities of it being alike, setting and producing graphitization. This transformation-to-bainite processing is applicable not only to a steel strip or a steel plate but the ingredient which could apply also to a wire rod or ** material, and carried out primary operation when special.

[0026] First, the transformation-to-bainite processing according to this invention heats steel in the temperature region of three or more Ac(s), and austenitizes it completely. and a larger cooling rate than the rate which passes the nose of a TTT diagram from this condition -- more than an Ms point (martensitic transformation start point) -- up to the temperature of the range of less than 350 degrees C -- cooling -- this temperature region -- for 10 - 60 minutes -- constant temperature -- after holding, it cools with the cooling rate more than air cooling or air cooling to a room temperature.
[0027] Larger cooling rate than the rate which passes the nose of a TTT diagram, When the temperature region below Ms point -350 degree C is hardened from the organization of austenite single phase It is the thing of a cooling rate which neither a ferrite nor a pearlite generates., In the case of steel which has the chemical entity of this invention, if there is a cooling rate 50 degrees C / more than sec, neither a ferrite nor a pearlite will generate.
[0028] Isothermal treatment temperature must be made into less than [Ms point -350 degree C]. By carrying out isothermal treatment at less than 350 degrees C, bainite is generated as lower bainite. Distinction of lower bainite is possible in that it has a more nearly needlelike gestalt compared with the upper bainite generated above this temperature region, and its hardness is still higher. That this invention steel demonstrates ultrahigh strength and toughness has the very detailed mixed organization of this lower bainite and retained austenite, Retained austenite is to show a TRIP phenomenon.
[0029] A TRIP phenomenon is the stability of retained austenite, That is, it is concerned with the ease of happening of strain induced transformation, Moderate stability which it metamorphoses [stability] moderately during plastic deformation and makes distorted distribution cause is needed. The stability of retained austenite is mainly decided by carbon concentration. Usually, in order to exist as retained austenite, 1.0 - 1.2% of carbon concentration is required, but in order to acquire the stability which shows a TRIP phenomenon, a high concentration carbon atom needs to be condensed. When especially this invention is so that target high-strength steel Stable retained austenite is needed by further high concentration., It is based on the following reasons.
[0030] Although the lower bainite which isothermal treatment temperature generated at less than 350 degrees C has a very high degree of hardness, since retained austenite is elasticity comparatively in itself, distortion is concentrated on retained austenite. For this reason, compared with the case, elasticity [bainite], strain induced transformation much more becomes easy to happen. In order to coexist with hard lower bainite and to show a TRIP phenomenon in the ultrahigh strength of the 2nd 1600-2300Ns [/mm] class like this invention steel, the carbon concentration in retained austenite is needed 1.5% or more.
[0031] this invention persons, constant temperature -- result of having inquired about the relation between retention temperature and the carbon concentration in retained austenite, this invention steel -- C-Si-Mn a system -- Cr -- adding carbide formation elements, such as Mo, V, and Nb, further -- constant temperature -- when retention temperature was less than 350 degrees C, it turned out that the retained austenite to which carbon concentration exceeds 1.5% is obtained. namely, the steel of the component range specified by this invention -- the temperature of less than 350 degrees C -- constant temperature -- by holding showed that the ultrahigh strength steel using the TRIP phenomenon of retained austenite was obtained.
[0032] in addition, constant temperature -- if retention temperature is lower than an Ms point, hardening martensite will generate and the mixed organization of bainite and retained austenite will not generate. For this reason, the Takanobu nature cannot be obtained. On the other hand, Retention temperature cannot obtain the tensile strength of two or more [1600Ns //mm] above 350 degrees C. therefore, constant temperature -- it is necessary to make temperature to hold into less than 350 degrees C more than an Ms point
[0033] this constant temperature -- the time amount held in a retention temperature region should just be 10 - 60 minutes. The amount of transformations to bainite has the inadequate holding time [in / in the steel of the component specified by this invention / the temperature region concerned] in less than 10 minutes, The carbon concentration in a non-metamorphosed austenite may not reach 1.5 %. In this case, although it is high intensity, it becomes lacking in ductility. On the other hand, if isothermal transformation time amount is lengthened not much exceeding 60 minutes, retained austenite will decompose, and carbide will

deposit, for this reason carbon concentration will fall again, and ductility will come to fall. Therefore, the time amount held in a less than 350-degree C temperature region more than an Ms point is good to consider as 10 - 60 minutes.

[0034] once -- this constant temperature -- since organization change will not be caused to cooling to a room temperature in the case if it is a cooling rate 1 degree C / more than sec after carrying out this time amount maintenance in a retention temperature region, it is satisfactory if it is a cooling rate more than air cooling.

[0035]

[Example] It is the chemical entity value of sample offering steel to Table 1. (% of the weight) It is shown. They are No.A, and B, C, D, E, F, G and H among these, The content of any one component is the comparison steel which separates from the range specified by this invention, and No.I, and J, K, L, M and N are the steel of component presentation within the limits of this invention. All were made into the steel plate with a thickness of 1mm through the usual hot rolling, softening, and cold rolling.

[0036] a cooling rate larger after heating each comparison steel A-H and this invention steel I-N to the temperature beyond those Ac3 transformation points and austenitizing them completely than the rate which passes the nose of a TTT diagram -- up to the temperature of the range of Ms point -350 degree C -- cooling -- this temperature region -- for 10 - 60 minutes -- constant temperature -- after holding, it cooled with the cooling rate of 2 degrees C/second to the room temperature. The heat treatment conditions of each sample offering steel were shown in processing No. of Table 2. The concrete conditions of each processing No. are shown in Table 3. Moreover, heat treatment which separates from the range which isothermal treatment conditions specify by this invention about this invention steel I-J was performed. The concrete condition was shown in processing No.6-8 of Table 3.

[0037] mechanical property (tension test value according to JIS 13B No.) of each steel which performed these processings ** The amount of retained austenites and the carbon concentration in retained austenite were measured, and the result was shown in Table 2. With the ingredient which heat-treated the range specified to said comparison steel as comparison material by this invention in Table 2, the ingredient which heat-treated the range specified to the steel which has the component presentation according to this invention as this invention material by this invention, and the example of a comparison, it heat-treats on the conditions of this invention out of range to the steel which has the component presentation according to this invention.

[0038]

[Table 1]

[0039]
[Table 2]

鋼No.	C	Si	Mn	P	S	Cr	Mo	V	Nb	備　考
A	0.80	1.96	0.52	0.012	0.006	0.01	tr	tr	tr	比較鋼
B	0.32	2.01	0.49	0.017	0.005	0.75	0.09	0.12	0.05	比較鋼
C	1.10	2.00	0.51	0.014	0.005	0.81	0.05	0.06	0.05	比較鋼
D	0.65	0.21	0.51	0.018	0.005	0.78	0.08	0.08	0.04	比較鋼
E	0.69	2.05	2.49	0.018	0.008	0.71	0.08	0.05	0.04	比較鋼
F	0.70	1.90	0.50	0.017	0.008	2.11	tr	tr	0.03	比較鋼
G	0.69	1.82	0.51	0.018	0.004	0.85	0.26	0.74	0.03	比較鋼
H	0.71	2.08	0.46	0.015	0.005	0.75	0.85	0.19	0.04	比較鋼
I	0.70	1.92	0.48	0.012	0.008	0.71	0.01	tr	tr	発明鋼
J	0.73	2.05	0.50	0.011	0.005	0.65	0.20	0.10	0.04	発明鋼
K	0.69	1.95	0.49	0.013	0.005	0.70	0.25	0.13	0.05	発明鋼
L	0.70	2.00	0.47	0.011	0.006	0.65	0.28	tr	tr	発明鋼
M	0.50	1.90	0.48	0.012	0.007	0.69	tr	0.20	tr	発明鋼
N	0.48	2.09	0.50	0.015	0.008	0.71	0.19	tr	0.05	発明鋼

[0040]
[Table 3]

	鋼No.	処理No.	0.2%耐力 (N/mm²)	引張強さ (N/mm²)	伸び (%)	硬さ (Hv)	γ_R量 (%)	γ_R中のC濃度 (%)
比較材	A	2	852	1215	16.8	356	12	1.2
	B	2	1286	1568	13.9	523	13	1.5
	C	2	669	1434	7.9	559	34	1.3
	D	5	1468	1768	6.1	580	0	—
	E	5	886	1631	2.3	543	22	1.1
	F	5	789	1703	3.1	576	19	1.0
	G	2	690	1619	1.6	795	27	1.1
	H	2	812	1543	4.9	756	23	1.2
本発明材	I	2	1167	2094	11.9	579	22	1.6
	I	4	909	2221	10.8	610	19	1.6
	I	5	1305	1803	12.3	561	26	1.5
	J	1	963	2234	11.4	584	23	1.5
	J	2	1215	1914	10.4	572	21	1.7
	J	3	1354	1882	10.3	570	19	1.5
	K	2	1059	2283	11.0	607	25	1.6
	L	2	911	2190	11.5	613	23	1.5
	M	2	1393	1888	12.7	559	18	1.7
	N	2	1240	1890	11.1	571	17	1.6
比較例	I	8	—	1029	0.2	862	29	1.1
	I	9	901	1471	28.3	388	34	1.5
	J	6	1057	1643	0.5	801	29	1.0
	J	7	1619	1998	7.1	605	15	1.3

処理No.	熱処理方法			
	オーステナイト化温度×保持時間	熱浴までの冷却速度	恒温保持温度×保持時間	室温への冷却速度
1	900℃×30分	50℃/秒	300℃×20分	2℃/秒
2	900℃×30分	50℃/秒	300℃×40分	2℃/秒
3	900℃×30分	50℃/秒	300℃×60分	2℃/秒
4	900℃×30分	50℃/秒	280℃×30分	2℃/秒
5	900℃×30分	50℃/秒	320℃×30分	2℃/秒
6	900℃×30分	50℃/秒	300℃× 5分	2℃/秒
7	900℃×30分	50℃/秒	300℃×90分	2℃/秒
8	900℃×30分	50℃/秒	220℃×30分	2℃/秒
9	900℃×30分	50℃/秒	380℃×30分	2℃/秒

[0041] The result of Table 2 shows the following thing.
[0042] Although the comparison material A2 heat-treats the steel with which the content of Cr does not add Mo, V, and Nb low, either, since graphitization has been caused at the time of softening at the time of steel plate manufacture, austenitizing is fully impossible and reinforcement is low to this ****. That is, the comparison steel A has small graphitization resistance.
[0043] Comparison material B-2 has low reinforcement. This is because the carbon content in steel is low.
[0044] Both the comparison material C2 has reinforcement and low ductility (elongation). This, It is because the carbon content in steel is excessive, so the amount of retained austenites increased too much.
[0045] The comparison material D5 has low ductility. since too little [this / the amount of Si] -- a transformation to bainite -- quick -- going on -- the constant temperature for 30 minutes -- it is because retained austenite became 0% by maintenance.
[0046] The comparison material E5 also has low ductility. This is because the amount of Mn is excessive, so the transformation to bainite became late too much and the gestalt of bainite also became big and rough.

[0047] Ductility is low, although the comparison material F5 heat-treats the steel which the large quantity was made to contain rather than this invention prescribes the amount of Cr(s). Since this has the excessive amount of Cr(s), a transformation to bainite becomes late too much, and own toughness of bainite falls.
[0048] Since the comparison material G2 has the excessive amount of V, a healthy bainite texture does not generate it, but its toughness is low. Moreover, since the comparison material H2 also has the excessive amount of Mo, a healthy bainite texture does not generate, but toughness is low. That is, elongation is comparatively [with high hardness] low, and proof stress is also low.
[0049] As opposed to this, Each of I2, I4, I5, J1, J2, J3, K2, L2, M2, and N2 of this invention material shows the super-reinforcement of tensile strength 1600-2300 N/mm2, and elongation is 10% or more. Moreover, also 0.2% proof stress More than 900 N/mm2 is shown. Therefore, according to this invention, it turns out that it excelled in ductility, providing ultrahigh strength, and the good ingredient of on-the-strength-ductility balance was obtained. In addition, in the case of this invention material, the carbon concentration in retained austenite has all become more than with 1.5 %, and the amount of retained austenites is also in about 15% or more and 30% or less of proper range.
[0050] however If the heat treatment conditions specified by this invention separate so that the examples I8, I9, J6, and J7 of a comparison may see, it cannot be satisfied with the steel of the chemical entity value

range specified by this invention of ultrahigh strength and toughness at coincidence.
[0051]
[Effect of the Invention] According to this invention, the ultrahigh strength steel with which TS excelled [2] in 1600-2300Ns /of ductility mm is obtained so that clearly from the above example.

[Translation done.]

* NOTICES *

CORRECTION OR AMENDMENT

[Kind of official gazette] Printing of amendment by the convention of 2 of Article 17 of Patent Law
[Section partition] The 4th partition of the 3rd section
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[Procedure revision]
[Filing Date] April 23, Heisei 11
[Procedure amendment 1]
[Document to be Amended] Specification
[Item(s) to be Amended] 0015
[Method of Amendment] Modification
[Proposed Amendment]
[0015] Although it is necessary to take such a thing into consideration synthetically and to decide the component presentation of steel in order to attain the aforementioned purpose This invention persons, If Cr and the steel which carried out optimum dose addition of Mo, V, the Nb, etc. further are used as a result of the fundamental research on these points in addition to C, Si, and Mn Graphitization resistance It can be made to improve. And detailed lower bainite generated at the time of transformation-to-bainite processing, the complex tissue which consists of stable retained austenite and detailed lower bainite generated, and TS which was very excellent in on-the-strength-ductility balance found out that the ultrahigh strength steel of the 2nd 1600-2300Ns [/mm] class was obtained.
[Procedure amendment 2]
[Document to be Amended] Specification
[Item(s) to be Amended] 0042
[Method of Amendment] Modification
[Proposed Amendment]

[0042] Although the comparison material A2 heat-treats the steel with which the content of Cr does not add Mo, V, and Nb low, either, since graphitization has been caused at the time of softening at the time of steel plate manufacture, austenitizing is fully impossible, for this reason reinforcement is low. That is, the comparison steel A has small graphitization resistance.

[Procedure amendment 3]

[Document to be Amended] Specification

[Item(s) to be Amended] 0048

[Method of Amendment] Modification

[Proposed Amendment]

[0048] Since the comparison material G2 has the excessive amount of V, a healthy bainite texture does not generate it, low [toughness], since the comparison material H2 also has the excessive amount of Mo, a healthy bainite texture does not generate it, but its toughness is low. That is, elongation is comparatively [with high hardness] low, and proof stress is also low.

[Translation done.]